Introduction to ACL Injuries in Women

An Honors Thesis (HONR 499)

by

Christine Gates

Thesis Advisor
Dr. David Pearson

Ball State University
Muncie, Indiana

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Abstract

Women are more active and involved in sports today than has ever been seen in the past. Because of this surge in women athletics, it has been observed that women are also more prone to injuries than their male counterparts. One of the major injuries seen within female athletes is an anterior cruciate ligament (ACL) injury in the knee. The ACL is widely recognized as the most important ligament in the knee due to its influence on mechanical stability and proprioceptive feedback. When injured, recovery can and usually takes months to complete. Finding ways to prevent women from experiencing an ACL injury is crucial to overall health and increased competiveness in the ever-growing world of women's athletics.

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Process Analysis Statement

As a current exercise science major and future physical therapy student in the upcoming fall, I knew I wanted to focus my paper on some type of sports injury and how to prevent it from occurring. Anterior cruciate ligament (ACL) injuries are very common in athletes and I have witnessed many friends suffer from these injuries in my nineteen years of playing soccer. As a future physical therapist, I will work with many patients who will or have suffered from an ACL injury. It is important for me to fully understand the complete scope of suffering a knee injury in order to help my patients heal properly to the best of my ability. To write the following thesis, I researched information about all aspects of the knee starting with the anatomy of the knee and ending with ACL injury prevention techniques. The research information that was used was found in scientific journals, with many of the articles written by physical therapists or orthopedic doctors. Throughout the process I learned that there has been a lot of research on ACL injuries, but scientists are having a hard time determining exactly why women are more prone to the injuries than men. Although a lot of research has been done on ACL injuries and prevention in women, further research would be even more beneficial toward solving why women suffer from so many ACL injuries.

Introduction to ACL Injures in Women

It has been estimated that in girls' high school sports alone, participation has increased over 900% since the introduction of Title IX (Horwitz, 2014). Title IX is a federal law that states any person, regardless of sex, should be allowed to participate in sports and have a fair opportunity at doing so. Along with this increase in women playing sports has come an increase in the amount of injuries, with many of those rates of injuries surpassing the rates that are witnessed in males. A major part of the body in a female where these sports-related injuries are seen is in the knee, specifically the anterior cruciate ligament (ACL). As more injuries are recorded, more research is gradually being put into why injuries occur more in women, and what can be done to help prevent women from experiencing ACL injuries in the first place.

Because of the knee joint's complexity, it is important to understand the anatomy of the knee in order to differentiate injuries to the knee and know how to treat those different injuries. The knee is the largest and most complex joint in the human body and is composed of many elements including bones, ligaments, cartilage, and tendons. There are four bones that join together to form the knee including the femur, tibia, fibula, and patella. All of the bones that form the knee joint are covered in articulate cartilage, a substance that decreases frictional forces between the bones. The four bones of the knee are then connected to one another in various ways by different ligaments in the knee. The ligaments of the knee are recognized as the stabilizers of the knee, providing optimal strength in different positions. The ligaments include the medial collateral ligament (MCL), lateral collateral ligament (LCL), posterior cruciate ligament (PCL), and anterior cruciate ligament (ACL). The most important ligament, as well as structural component

overall, in the knee is the ACL. The ACL is specifically located in the middle of the knee and forms a cross with the PCL. The ACL connects the anterior portion of the tibia to the posterior portion of the femur.

The ACL holds high importance in the knee joint because it plays a vital role during many actions and movements performed by the body. The ACL's primary functions all include preventing certain movements of the knee from occurring in order to prevent injury. The motions that the ACL prevents from occurring include "excessive anterior translation of the tibia on the femur, excessive internal rotation of the tibia, excessive valgus forces, and knee hypertension" (Petterborg, 2012). In layman's terms, the ACL keeps the shinbone from sliding too far forward, prevents inward rotation of the shinbone, protects against bending of the knee sideways towards the body, and prevents the knee from excessively straightening beyond the normal range of motion. Because of these many functions, the ACL is essential for normal knee function and stability. Beyond the mechanical support the ACL offers in the knee joint, the ACL is also responsible for contributing to neuromuscular control using sensory receptors. It is unknown exactly how large of an impact the ACL's sensory receptors have on neuromuscular control, but it has been discovered that muscle stabilization in the knee is made possible by the receptors (Liu-Ambrose, 2003).

Because of the complexity of the knee joint, it is prone to many injuries. Injuries to the knee, and specifically the ACL, are generally consequences of "muscle weakness, incorrect technique during exercise, and improper body alignment while exercising" (Peak Performance, 2015). Furthermore, injuries to the ACL may also include either overstretching or tearing of the ligament, with the highest amount of injuries occurring in

a twisting motion. Over 70% of ACL injuries are reported as non-contact, with most of the movements involved being deceleration and cutting (Silvers and Mandelbaum, 2007). Non-contact means that no outside forces contributed to the injury. An example of an outside force injury could include another athlete running into the side of the knee, causing a once straight leg to become quickly bent at the knee.

There are many ways in which an ACL injury can occur and there are also many different factors that contribute to the rate of ACL injuries seen in different populations. Three major factors that may dictate the rate of injuries include age of the individual, their gender, and the individual's level of athletic training. The highest incidence of ACL injuries in any population is seen in female athletes who are between the ages of 15 and 19 years old (Dharamsi, A and LaBella, C, 2013). During the phase of adolescence, the risk of an ACL injury in females is at its peak. The risk is lower in childhood and also begins to decrease again when the female reaches early adulthood. It is believed that the younger age groups are at a lower risk of injury because the ligaments are stronger than the bones and the growth plates in the childhood phase. This means it would be more likely for the child to experience an injury to the bone, including a break or fracture, compared to an injury to a ligament. Furthermore, the risk of an ACL injury drops back off in early adulthood in women because of hormonal factors.

It is well recognized that ACL injuries occur more in females than males, but the reason for this higher frequency is not easily explained. Differences seen in women that are thought to be associated with the increased risk of ACL injuries in females includes a narrower intercondylar notch, smaller ACL, wider pelvis, lax ligaments, slower reflex time, greater quadriceps/hamstring strength ratio, estrogen levels, and flat-footed landing

(Horwitz, 2014). The intercondylar notch is the groove in the femur where the ACL is located. This anatomical feature is smaller in females, and so is the ACL itself, both causing the ACL to be more prone to injury. Because women have a wider pelvis, their thighbones angle downward more prominently than in men. This causes women to have a greater "Q" angle, meaning they are more naturally in a knock-knee alignment. In a knock-knee position more pressure is focused on the inside of the knee, making it easier to tear the ACL. Lax ligaments are also a factor scientists believe contributes to greater ACL injury rates in women. Lax ligaments contribute to ACL injuries because with more "give" in the ligaments comes greater flexibility. This can cause overstretching of the ligaments to occur, possibly ending in an injury. Slower reflexes are another contributor because scientists believe the muscles stabilizing the knee, including the ACL, take a millisecond longer to react in females. This time may not sound like much, but when cutting or decelerating that millisecond makes a large difference. If the muscles are not stabilizing the knee during a quick motion, an injury can more easily occur. Another anatomical feature observed in women is poor hamstring strength. This means it is likely the hamstring is not able to balance the strength of the opposing quadriceps muscle, leading to a lot of strain placed on the ACL. This low hamstring strength and strain on the ACL has been linked with ACL ruptures. The next ACL injury contributor in women is the change in estrogen levels seen during menstruation. Scientists have debated whether estrogen levels make a difference in rates of injury, but many scientists studying the ACL say menstruation estrogen levels make ACL's more prone to injury. The final observation by scientists that they think may contribute to injuries seen in women includes a flat-footed landing after a jump. Women tend to land flat-footed more so than men when not

properly trained to land on the balls of their feet. When you land flat-footed, the calf muscle is not absorbing the force of the landing and the knee is not in a proper position. This may cause the knee to buckle and the ACL to rupture. All of these factors in women, including a narrower intercondylar notch, smaller ACL, wider pelvis, lax ligaments, slower reflex time, greater quadriceps/hamstring strength ratio, estrogen levels, and flat-footed landing, may contribute to women being more susceptible to injuries. Scientists have not been able to precisely prove that these factors are always to blame in the large amounts of observed ACL injuries, but they do believe these factors are the main contributors.

The rate of ACL injuries, specifically in women, has increased over the years and has become one of the most problematic sports injuries. Because of this rise in incidence rates, more scientists are studying why the injuries are occurring and how to prevent the injuries from occurring in the first place. According to Dr. Steven Horwitz, "Several recent studies demonstrate that the rate of ACL injury among women can be significantly reduced by following a proper neuromuscular training and conditioning program" (Horwitz, 2014). A neuromuscular training program focuses on training the brain and muscles to react properly and communicate with one another in order to produce proper form and avoid injury. To counteract force, which is inflicted on the body during sports, and even in everyday life, the body must fire nerves, telling muscles how to function. Without neuromuscular function, it would be very difficult for the body to maintain balance, stability, or even move properly. Neuromuscular training pre-programs the brain to perform safe movement patterns before an injury is able to occur.

Preventative neuromuscular training is key to minimizing the rate of ACL injuries in women and has been proven to be the most efficient and effective. Within any age-group or gender, "neuromuscular training programs can effectively reduce primary-ACL injury prevalence by between 43.8% and 73.4%" according to a study reported in the *Journal of Orthopedic and Sports Physical Therapy* (Peak Performance, 2015). Furthermore, the study also noted that neuromuscular training would be especially beneficial for adolescent females as their risk of ACL injury could drop by as much as 72% with the implementation of a proper neuromuscular training program. While neuromuscular training has been found to be very beneficial, it does not completely take away the chances of an ACL injury from occurring. Some ACL injuries are unavoidable, but taking precautions, such as utilizing a proper training program, have been proven to greatly help. In a study performed by Dr. Timothy E. Hewett that was published in the *American Orthopedic Society for Sports Medicine*, it stated that "Neuromuscular training is an intervention that can have a biomechanical effect, such as decreased landing forces and adduction and abduction moments, as well as a physiological effect, such as decreased estrogen levels and increased hamstring-to-quadriceps ratios (Hewett et al., 1999). Neuromuscular training affects the body in more ways than just strengthening muscles.

There are many different neuromuscular training programs already developed to aid in avoiding ACL injuries and they mainly focus on increasing strength and balance in the knee and the muscles around the knee. To achieve the goals of increased strength and balance, the neuromuscular training programs generally consist of plyometrics and movement, core strengthening and balance, resistance training, and speed training (Peak

Performance, 2015). The most well-known neuromuscular training program for the prevention of ACL injuries was developed by the *Santa Monica Orthopedics and Sports Medicine Research Foundation* and it is called the Prevent Injury and Enhance Performance Program, more commonly refereed to as the PEP program. The PEP program involves different phases of a workout including a warm-up, stretching, strengthening, plyometrics, and sport-specific agility exercises. It only takes 15-20 minutes to complete PEP per day, and it is recommended that athletes complete the program three times per week (The Santa Monica Sports Medicine Research Foundation, 2017). One of the most important factors to keep in mind while completing the PEP program is proper form. To ensure proper form and movement techniques throughout each exercise, it is recommended the program be completed under the supervision of a trainer or coach who is knowledgeable in proper techniques of exercises. The program includes multiple phases with different exercise in each phase, it tells how long to complete each exercise, and it also provides proper instruction for technique and form (Appendix A) (The Santa Monica Sports Medicine Research Foundation, 2017).

While neuromuscular training is the most effective form of preventative treatment, like Horwtiz stated in his study, it is also important for women to incorporate a conditioning program into sports training in order to strengthen muscles (Horwitz, 2014). Neuromuscular training strengthens muscles, but its main function is to train the brain to work with the muscles and ensure proper form in training and during events. A conditioning program's main goal is to then strengthen muscles, which also helps prevent injuries from occurring. Greater muscle mass translates to greater support of the bones in the body, allowing for more stability in the joints throughout the entire body. To prevent

ACL injuries, one would need to focus on strengthening the muscles around the knee and the muscles that keep the knee stable. The main muscles to focus on in an ACL prevention program would include the gluteus maximus, gluteus medius, gluteus minimus, tensor fascia lata (hip), hamstrings, and the core muscles (Dharamsi, A and LaBella, C, 2013). To strengthen these muscles a full workout plan could be created with the sole focus being on ACL prevention, or exercises to strengthen the gluteus maximus, gluteus medius, gluteus minimus, tensor fascia lata, hamstrings, and core muscles could be added to an already developed workout plan depending on the athlete's preference. There are many different exercises that target the appropriate muscles and examples of those different exercises range in difficulty and experience (Appendix B).

To ensure female athletes are getting the proper amount of ACL prevention training, coaches should incorporate programs such as the PEP program and conditioning programs into practice each week of training. In order to keep athletes on the field and out of the doctor's office and rehabilitation, it is important that injuries are addressed before they even have a chance to occur. With more and proper additions of neuromuscular training and conditioning to practices and everyday life, the rate of ACL injuries will drop drastically. Research shows that women have a higher possibility of suffering an ACL injury than men, but research also shows that there are ways to lower the risk of getting an injury. Because of the knee's complexity and the ACL's major functions in the body, it is important that athletes protect the knee from injury in order to be fully functional and competitive. It is imperative that women take extra precautions in sports by engaging in preventative ACL injury plans in order to reduce the high incidence of injuries seen in women athletes. With increased professional and personal knowledge

of ACL injuries and how to prevent them, ACL injuries in women will become less of an issue in the future.

Appendix A

Phase 1: Warm-up			
Exercise	Jog Line to Line	Shuttle Run	Backward Running
Purpose	Slowly prepares athlete for training session while avoiding risk of injury	Engages hip muscles and promotes increased speed	Engages hip extensors and hamstrings
Proper Technique	Keep the knee, hip, and ankle all in alignment with one another	Discourage inward caving of the knee joint	Land on toes and maintain a slight bend in the knee
Time	30 seconds	30 seconds	30 seconds

Phase 2: Strengthening			
Exercise	Walking Lunges	Russian Hamstring	Single Toe Raises
Purpose	Strengthens the quadriceps (thigh) muscles	Strengthens hamstring muscles	Strengthens calf muscles and increases balance
Proper Technique	Keep front knee over ankle and keep front knee from caving inward	Knee, hip, and shoulder should be in a straight line	-------
Time	1 minute	1 minute	1 minute

Phase 3: Plyometrics					
Exercise	Lateral Hops Over Cone	Forward/Backward Hops Over Cone	Single Leg Hops Over Cone	Vertical Jumps with Headers	Scissors Jump
Purpose	Increases power and strength, emphasizing neuromuscular control	Increases power and strength, emphasizing neuromuscular control	Increases power and strength, emphasizing neuromuscular control	Increases height of vertical jump	Increases power and strength of vertical jump
Proper Technique	Soft landing on balls of feet and keep a slight bend in the knee	Soft landing on balls of feet and keep a slight bend in the knee	Soft landing on balls of feet and keep a slight bend in the knee	Soft landing on balls of feet and keep a slight bend in the knee	Knee should be stable and directly over the ankle; Soft landing on balls of feet and keep a slight bend in the knee
Time	30 seconds	30 seconds	30 seconds	30 seconds	30 seconds

Phase 4: Agility			
Exercise	Forward Run with 3 Step Deceleration	Lateral Diagonal Runs	Bounding Run
Purpose	Increases dynamic stability of the ankle/knee/hip complex	Deters a "knock knee" position from occurring	Increases power, speed, and hip flexion strength
Proper Technique	Do not allow knee to cave in	Slight bend in knee and hip; make sure knee stays over the ankle	Land on balls of feet with slight bend in knee and a straight hip
Time	1 minute	1 minute	1 minute

Phase 5: Stretching					
Exercise	Calf Stretch	Quadriceps Stretch	Figure Four Hamstring Stretch	Inner Thigh Stretch	Hip Flexor Stretch
Purpose	Stretches calf muscle of the lower leg	Stretches quadriceps muscle of the front thigh	Stretches hamstring muscles of the back of the thigh	Elongates the muscles of the inner thigh (adductor muscles)	Elongates the hip flexors of the front of the thigh
Proper Technique	Do not bounce during the stretch	Do not allow knee to wing out to the side and do not bend at the waist	Do not round back and do not bounce during stretch	Do not bounce during the stretch	Keep hips square with the shoulders
Time	1 minute (2 reps, 30 seconds each)	1 minute (2 reps, 30 seconds each)	1 minute (2 reps, 30 seconds each)	1 minute (2 reps, 30 seconds each)	1 minute (2 reps, 30 seconds each)

Appendix B

Muscle Group	Exercise 1	Exercise 2	Exercise 3
Gluteus maximus	Body weight squat	Gluteal curl	Glute bridge
Gluteus medius and minimus	Hip rotation	Side plank	Hip hitch
Tensor fascia lata	Clamshell with band	Side lying hip abduction	Fire hydrants
Hamstrings	Deadlift	Barbell back squat	Leg curl
Core Muscles	Plank	Reverse crunches	Bicycle crunches

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